

## 2. The 200-mile fishline

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Fishing has always been a marginal enterprise. Unlike highly sophisticated terrestrial farming (as practiced in Japan, Netherlands and the United States), fishing in many parts of the world is not much different today than it was hundreds of years ago. In Malaya, for example, the average catch per man-year is about 4 tons. Even though fishermen from the leading fishing nations of the world can easily equal this tonnage in a day, they are still hunting—not farming—fish.

### *Introduction*

Much has been said regarding the practicability of farming, or culturing, marine organisms. Today, however, “sea farming” (aquaculture or mariculture) does not exist on a significant scale. In fact, our knowledge of the oceans is so meager that it is difficult to predict when sea farming may become an economic reality. This situation does not preclude research into the problems of aquaculture. Indeed, such efforts must be made. At the same time, however, great strides must be made in fishery technology and bio-physical oceanography to help forestall wholesale starvation.

A fishery must react to the departures from the normal ocean situation, and it is the prediction of these departures that is imperative. Only by sufficiently early awareness of deviations from the normal can economic preparations be made to (1) realize the most profit, (2) mitigate the losses, and (3) manage the crop.

For ocean fish, such as tuna, a change in ocean circulation may, and frequently does, shift the center of fish availability by 2,000 miles. It depends on where the fishermen are as to whether this results in a “boom” or a “bust.” And, if they are caught in the center of the population with only two vessels, they still have a “bust.”

When currents change in position or force, the qualities of the water in the affected area also change. The result can be the introduction of an en-

vironment which may be either beneficial or detrimental to the organisms, or the introduction of food or predators. The time of change is critical; for what might be predators to larvae may be food for adults. The complexities of these biophysical systems are enormous and the ramifications seem infinite. Furthermore, the oceanic processes involved are linked closely with the atmosphere, and, necessarily, wax and wane with what is going on in the marine layer of air.

To unravel these tangled systems is a monumental task which is far from completion. Except for generalizations, the many years of scientific research of the great fisheries have added but few scattered pieces to the great puzzle. This is primarily because the phenomena influencing any fishery are generated "over the horizon," beyond the area of study. And, because the processes that are responsible begin as ocean-air interactions, the pieces of the puzzle are unlikely to appear until such reactions can be studied synoptically on a worldwide basis.

### *The view from space*

The first reaction to the suggestion of "fishing" from orbital altitudes of 200 miles must be skepticism. Yet, an evaluation of photographs taken by Gemini astronauts makes it clear that the oceans can be studied from space. Some features of the sea surface unknown to man were photographed and other features, suspected from limited data, were sharply defined.

These amazing photographs become even more unbelievable when the simplicity of the camera system is considered. The Hasselblad 500C is an excellent camera, but unsophisticated when compared with aerial cameras, and it was hand-held by the astronauts. The tremendous usability of the photographs is a clear tribute to the ingenuity and enthusiasm of the astronauts.

The combination of the ocean features that can be seen and the simple camera system employed leads to the optimism concerning oceanographic research from space. With cameras specifically designed for the purpose, coupled with other remote sensors, the view-from-space can be as significant to oceanography as was the Challenger Expedition in 1872.

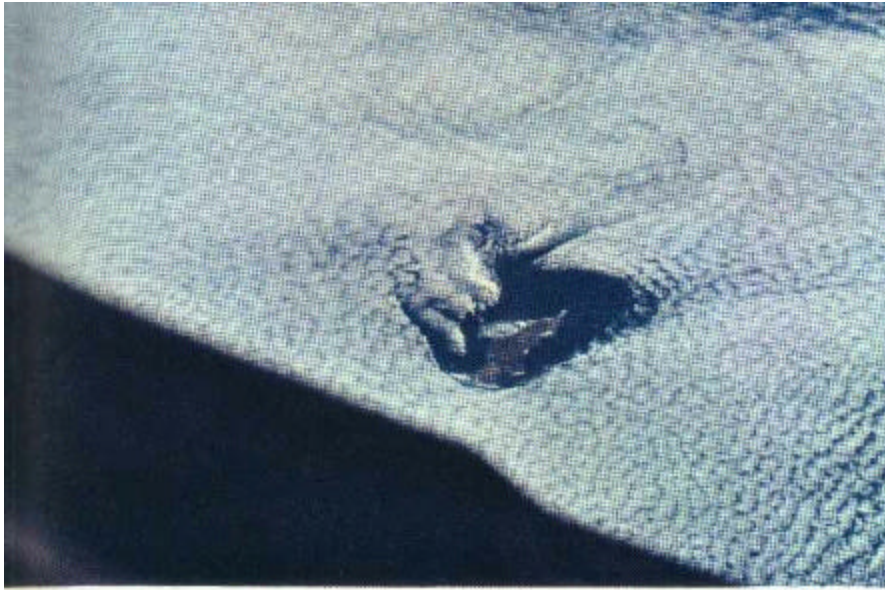
Let us now look at some of the features that were seen by the astronauts, and that we can see through the lens of the Hasselblad camera.

### *Clouds and Guadalupe Island*

The ocean waters of the coasts of California and Baja California are cool in response to the major north to south circulation in the eastern Pacific Ocean. Stratus and stratocumulus clouds form over the cool waters and are nearly constant features of the overlying marine atmosphere. The normal atmospheric circulation over this portion of the Pacific Ocean is also north to south, though variations respond to seasonal modifications in the Hawaiian High Pressure System and local conditions usual to any coast.

Figure 2-1 shows a typical low layer of stratocumulus clouds moving at 6-10 knots past Guadalupe Island. The island peaks reach 4,500 feet





*Figure 2-1: NASA/MSC photograph of Guadalupe Island, Baja California, Mexico, and Vizcaino Bay shows a typical low layer of stratocumulus clouds moving at 6 to 19 knots past Guadalupe Island. The photo was taken from an altitude of 130 nautical miles with an 80-mm lens by astronauts Col. L. G. Cooper and Cdr. Charles Conrad, Jr., during Gemini flight V on August 21, 1965.*

and thereby project through, and interfere with, the cloud layer. A "shock" or "bow" wave spreads from the north end of the island, similar to waves formed by a ship moving through water. Downstream, south of the island, von Karman eddies rotating to the right and to the left are formed as a turbulent "island wake."

These cloud features, waves, and eddies were photographed during four Gemini missions. They must, therefore, be considered climatic features of the Guadalupe marine atmosphere.

Similar waves and eddies appear in the water around islands (Figure 2-3). It is clearly necessary to investigate the details of these fluid motions for proper analyses of atmospheric and ocean flows.

The sun is reflecting from the land area of French Somali, so that just the edge of the reflection extends over the western Gulf of Aden in Figure 2-2. The variation in the reflection from the water is caused by differences

*An eddy and the Gulf of Aden*



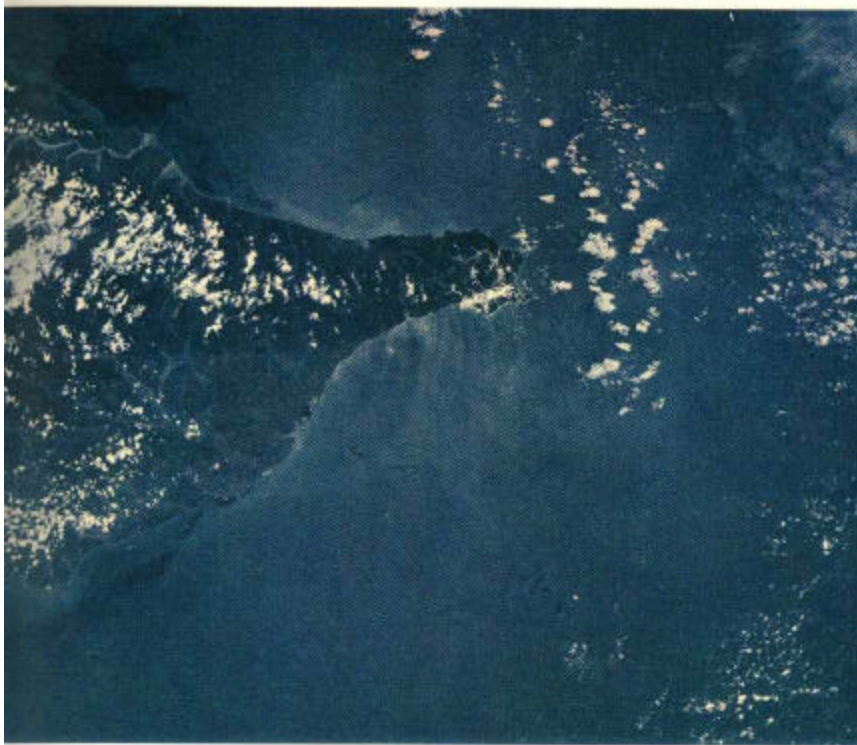
*Figure 2-2: NASA/MSR photograph of the Red Sea, Gulf of Aden, Ethiopia, Somali, French Somali, Saudi Arabia, Yemen, and South Arabia taken from an altitude of 380 nautical miles with a 38-mm Biogon wide-angle lens. The photo was taken by astronauts Cdr. Charles Conrad, Jr., and Cdr. Richard F. Gordon, Jr., during Gemini flight XI, September 14, 1966.*

in the roughness of the water surface. Water movement with the wind results in a smoother surface than movement into the wind, or no movement. The diffuse reflection is roughened water; the dark blue is smooth water (slicks). Winds on September 14th were light and variable, and were blowing about 4 knots from the west at the time of this photograph.

In September, the water level in the Red Sea recovers from the great loss by evaporation during the preceding winter. The warm (90°F), highly saline (39-40 percent) water begins to pour over the sill (350 feet deep) of the Strait of Bab al Mandab into the western Gulf of Aden. Since these Red Sea waters are more dense than those of the surface layers in the Gulf of Aden (salinity 36 percent), they sink to a depth of some 600 feet, and subsequently flow through the Gulf of Aden to join the intermediate (2,400 feet) water of the western Indian Ocean.

The eddy system, seen in the sun glitter of this photograph, is the surface flow and turbulence caused by the waters of the Red Sea flowing into and beneath the surface layers of the Gulf of Aden. Areas of divergence





*Figure 2-3:  
NASA/MSR photograph  
of Taiwan taken with  
an 80-mm lens by  
astronauts Cdr. John  
W. Young and Lt. Col.  
Michael Collins  
during Gemini X  
flight, July 20,  
1966.*

and convergence can be delineated, and if photographs were taken with a longer focal length lens, turbulent eddies 2-30 miles in diameter could be mapped.

The portion of the flow visible in this photograph is 135 miles long and 75 miles in diameter. The next photograph, not shown here but taken seconds later, outlined the extension of the system along the Somali coast; the two together gave an instantaneous view of a current system 250 miles long. Such current systems can confine significant fisheries, and conceivably do, in the Gulf of Aden where populations of pelagic fish are known to be large.

The major current system in the western Pacific Ocean flows south to north past Taiwan. Around the island, and especially in the Formosa Straits, the currents are complicated by the tides, which ebb to the south along the southern shores of Taiwan.

On July 19, the day before the photograph shown in Figure 2-3 was taken, tropical storm Nina was about 90 miles east of Taiwan. The storm was not well developed and winds of Beaufort Force 3 were the highest recorded. By 1200 GCT, July 20, the storm had dissipated and winds of Force 2 blew around Taiwan from an easterly direction.

*Upwelling and  
Taiwan*

In the photograph, the light blue of the sea is the result of a diffuse sun's reflection from an evenly roughened sea surface. Winds from the east and northeast increased the roughness of the northerly flowing waters. The reflective, specular, pattern from the sea surface thus depicts the features of water motion around the southern end of Taiwan.

The major current is parted by the island, much as a ship parts the water. As the "bow" wave spreads from the island, upwelling must take place near the shore. The dark blue water is partly upwelled water.

The fishing ports along the west coast of Taiwan are concentrated north of the lagoonal complex on the southwest coast.

#### *A sea breeze and India*

The cloudless skies along the entire coast of India are probably the result of subsiding air, as would occur during the daytime sea breeze. The weather map of 1200 GCT, 5 hours after the photograph in Figure 2-4, was taken, depicted the winds blowing toward the shore along all coasts. There was a calm in the center of India and a slight low pressure system over the northern part of the subcontinent. Temperatures of coastal air were about 80°F and temperatures of inland areas were 7-10°F warmer. Conditions were typical of a sea breeze day.

The ability to "see" such a system *in toto* is tremendously significant. Not only can the seaward extent of the sea breeze be precisely measured for the first time, but sea-surface wind drift, areas of potential upwelling, and convergences can be plotted synoptically for an entire coast. Were such a view available daily, the value to fisheries, shipping and meteorologists would be incalculable.

Seaward of the sea breeze zone, the polygonal, Benard cells of cumulus clouds indicate even distribution of water temperatures and the lack of surface winds.

#### *A divergence and Florida*

Although the high-oblique photograph in Figure 2-5 is spectacular in the area covered and the view, one might suspect that the sun's reflection, the resulting over-exposure, and lack of detail have produced a noninterpretable photograph. On the contrary, the picture provides some of the most significant oceanographic information acquired from orbiting spacecraft.

The view is to the southeast just after the Gemini XII spacecraft passed over the east coast of Florida. The Florida Keys, the Marquesas, and the Dry Tortugas lie in the center of the sun's reflection from the sea. To the left is Little Bahama Bank, with Grand Bahama Island (under large cumulus clouds) and Little and Great Abaco Islands. Eleuthera Island is almost entirely under clouds, but New Providence Island, on which is

*Figure 2-4: NASA/MSC photograph of India, Ceylon, Laccadive Islands, and the Bay of Bengal taken from an altitude of 480 nautical miles with a 38-mm Biogon wide-angle lens by astronauts Cdr. Charles Conrad, Jr., and Cdr. Richard F. Gordon, Jr., during Gemini flight XI on September 14, 1966.*









*Figure 2-5: NASA/MSR photograph of Cuba, the Bahama Islands, and the southern half of Florida taken from an altitude of 180 nautical miles with a 38-mm Biogon wide-angle lens by astronauts Capt. James A. Lovell, Jr., and Lt. Col. Edwin E. Aldrin, Jr., during Gemini flight XII on November 12, 1966.*

located the city of Nassau, is visible between two cloud lines. Great Bahama Bank, with Andros and Bimini Islands, extends south toward the Oriente Province of Cuba. Eastern and central Cuba have a dense cloud cover, but the area around Havana and the Isla de Pinos is rather clear. Near the horizon, far to the west, is the Yucatan Peninsula.



The wind was blowing to the southwest over the Bahama Islands, swinging more to the west over Cuba and Florida. Even were data not available from weather stations, the wind streamlines are readily discernible from the cloud lines. Wind slicks, as a result of lesser wave action and thus smoother water, are visible in the sun's reflection (glitter) downwind (leeward) from islands, shoals, and headlands. These slicks are visible only because the glitter is in the field of view. The specular reflection differs from surfaces of different texture. Consequently, slicks can be outlined over the Little Bahama Bank, west of Cape Sable, Florida, and west of the Peninsula de Zapata, Isla de Pinos, and Cabo San Antonio—all Cuban lands.

Another slick lies offshore but parallel to the west coast of Florida. Here the water is roughened near shore and far offshore, causing a diffuse reflection in the sun's glitter. In between is darker blue (smoother) water. Because this smooth water is offshore and not formed as a lee-effect, the implication is that the water is moving with the wind. Thus, the landward edge of the dark blue water is a divergence where subsurface water is rising to the surface. It is hardly coincidental that these waters harbor a significant fishery.

The nose of the spacecraft points toward the near shore portion of a line of cumulus clouds which persistently marks the landward border of the Gulf Stream. Beneath the loop extending from the spacecraft is the linear slick field marking the seaward boundary of the Gulf Stream. The meandering nature of the boundary, as the current moves past the Little Bahama Bank, is clearly defined.

The oceanographer, meteorologist, and geologist can learn much from this one photograph; this photograph which was called "poor" photographically.

These are but 5 of 575 photographs taken by the Gemini astronauts from which some information about the sea can be gleaned. From these few examples, it is clear that the view-from-space lays before the oceanographer many physical features of the sea that influence fisheries—features which until now he had no hope of seeing.

*Conclusion*

1. Contribution No. 254, Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas.

*References*